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EVALUATION OF STABILITY OF EARTH-FILL DAM BASED ON STRENGTH OF FROZEN ZONES OF ITS PROFILE

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When planning a permafrost dam it is necessary to consider that the freezing of its lower wedge due to natural cooling of the surface of the lower slopes and the transfer of cold from the permafrost curtain may take 3 to 4 years if the soil is not allowed to freeze layer by layer during the filling process. This report discusses the strength and stability of earth filled dams based on durability of frozen zones of its profile.

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NOTICE

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1. Strength of Prefrozen Core of Permafrost Plate

When planning a permafrost dam it is necessary to consider that the freezing of its lower wedge due to natural cooling of the surface of the lower slopes and the transfer of cold from the permafrost curtain may take several years (at least 3-4) if the soil is not allowed to freeze layer by layer during the filling process.

The width of the frozen core of a permafrost dam should be sufficient to ensure stability if the reservoir fills before the thrust prism is completely frozen and the core receives the total dynamic pressure on the dam. It is recommended that the total stability of an earth-fill dam with a frozen core be evaluated on the basis of the approximate plane [possibly displacement] (Figure 1) under the following simplifying assumptions:

the width of the frozen core b is constant through the height of the dam;

the thawed soil that is filled in the body of the lower prism, to the time of [possibly complete] freezing of the core to width b, retains a positive temperature in a substantial part of its volume;

thawing of the glacial permafrost soil to depth h_{fr} occurs in the base of the thaw zone of the lower prism due to [two words illegible].

The thawing ice-saturated soil of the foundation of the lower prism, which exists in the supersaturated state, exhibits [one word illegible] zero resistance to displacement;

under the influence of the heat of the reservoir, or [two words illegible] during the construction period, by the time of completion of the core [three words illegible] of the upper wedge, thawing of the [one word illegible] soil occurs to a depth h_{fr}, the angle of internal friction and the [one word illegible] of the thawing soil, due to their low [possibly values], are assumed to be equal to zero for the purposes of approximate calculation;

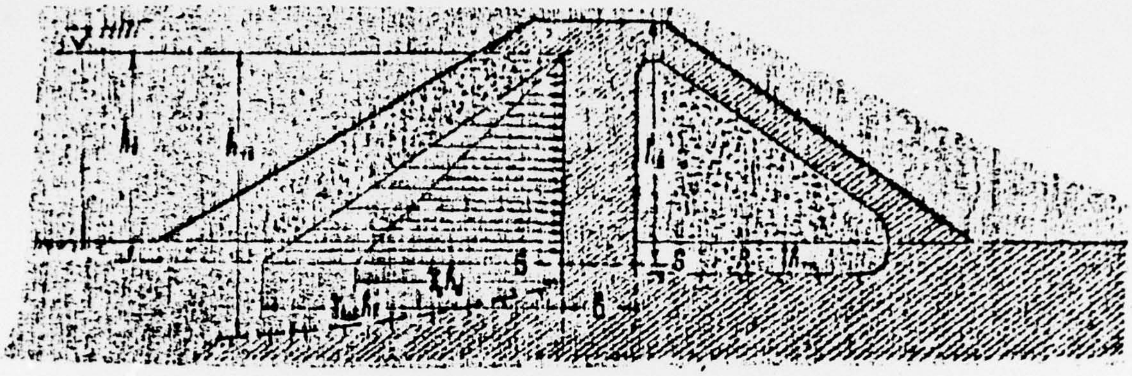

Figure 1. [НПГ=Normal backwater level].

during [one word illegible] of the upper wedge of thawed [possibly compacted] soil, the lateral pressure of the soil on its [possibly frozen] surface [one or two words illegible] core may be assumed equal to zero, since thermal subsidence of the thawing foundation is accompanied by the formation of straining stresses and subsidence cracks at the interface between the soil of the upper wedge and the top face of the core;

above the NPG [Normal backwater level] the core does not experience lateral pressure from the frozen layer of soil on the crest;

during erection of the upper prism with permafrost soils that are structurally unstable after thawing, it is necessary to consider in the calculation the lateral pressure of the supersaturated soil mass with zero internal friction angle and adhesion;

the core may be displaced in some plane S-S under the influence of the hydrostatic pressure of water and lateral pressure of the [possibly curtain] soil of the upper prism;

the plane S-S is located at depth h_s, for which the values ϕ_{th}, C_{th} of the thawed layer h_{th} may be assumed equal to zero;

the lower thrust prism, since it has no adhesion with the base due to the equality to zero of the values ϕ_{th}, C_{th} in the contact layer of the thawing soil of the floor, from the time of its complete freezing does not contribute to the resistance to displacing forces -- the lateral pressure of the soil of the upper prism and hydrostatic pressure of water;

the resistance of the frozen soil of the core to displacement R^H_{dis} is taken in accordance with SNIP [Construction norms and regulations] P-B. 6-66 for the average calculated temperature of the permafrost wall at depth h_s.

The approximate evaluation of the resistance of the permafrost core to displacement in plane S-S, corresponding to the time of zero displacement resistance of the lower thrust prism, may be found on the basis of the following formulas:

a) for the case of the absence of lateral pressure from the soil of the upper thrust prism

[cg=dis]

$$b^2 > \frac{\gamma_в h_в^2}{2(\gamma_м h_s + R^н_{cg})} \qquad (1)$$

b) for the case of the simultaneous action of hydrostatic pressure and lateral pressure from the thawing soil mass

[в=w; взв=cur]

$$b^2 > \frac{h_в^2(\gamma_{взв} + \gamma_в)}{2(\gamma_м h_s + R^н_{cg})}, \qquad (2)$$

where γ_m is the density of the permafrost soil of the core, kg/m^3; γ_w is the density of water, kg/m^3; h_w is the depth of the water that saturates the upper slope, m; γ_{cur} is the density of the curtain soil of the upper wedge, kg/m^3.

2. Stability of Frozen Soil Layer on Lower Slope of Thawed Dam

During calculations of the strength of a thawed earth-fill dam it is necessary to examine the version of the failure of drainage and loss of water impermeability of antifiltration systems, when hydrostatic pressure and the pressure of the soil of the thaw zone are absorbed by the waterproof frozen layers on the lower contour of the lower thrust prism.

The resistance of the frozen soil layer of the lower slope to surfacing under the influence of the hydrostatic pressure of the water that saturates the thaw zone of the dam in the case of failure of antifiltration and drainage systems, should be estimated under the following simplifying conditions (Figure 2a, b):

the thickness of the frozen layer is assumed to be constant through the length of the slope and equal to b, in meters;

the broken profile of the slope is drawn as a straight line, inclined to the horizon at angle α;

in the absence of through [possibly thawing] in the base of the slope and drainage tunnel in the body of the dam, filtration water does not seep onto the slope outside of the slope freezing zone and the freezing soil layer merges with the permafrost foundation soils;

hydrostatic pressure W is transmitted to the base of the permafrost layer through the entire length l and displacement (surfacing) of the mass

of frozen slope in the direction of action of force W occurs on the planes A-A and B-B. The forces of resistance to displacement are the weight of the mass P (the value P_w, the projection of force P onto the direction of action of force W, is taken into consideration in the calculation) and the resistance of the frozen soil to displacement R^H_{dis}, determined in accordance with SNIP P-B.6-66, depending on the calculated temperature of the frozen layer, averaged through thickness b. It is recommended in the calculation to use the minimum values of R^H_{dis}, corresponding to the period of maximum development of the seasonal thaw layer on the slope.

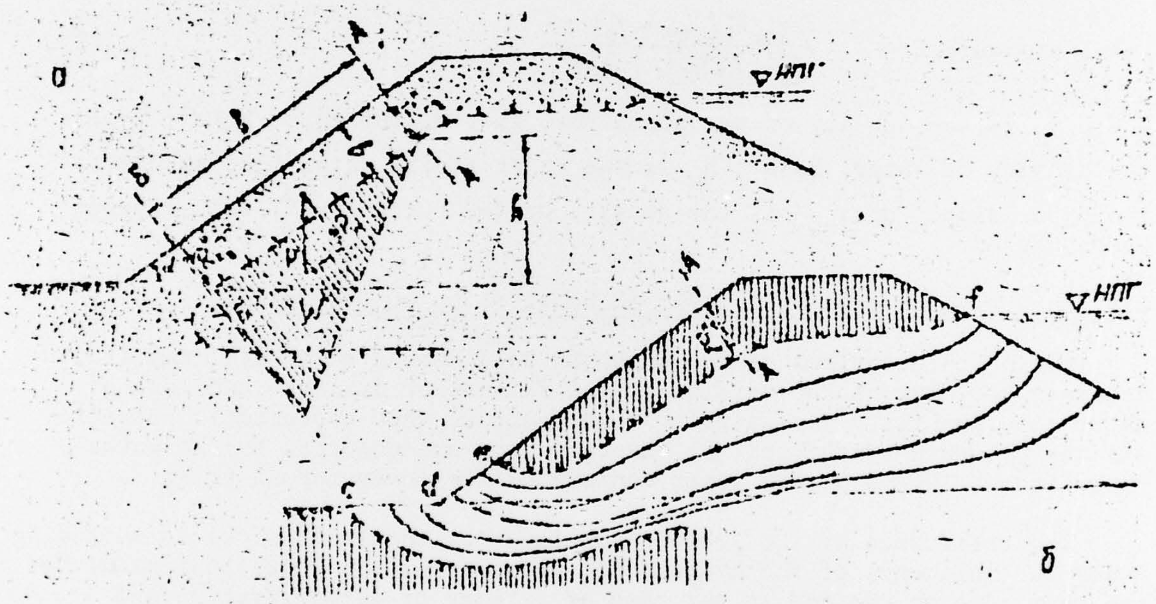

Figure 2.

For the state of ultimate equilibrium (when the [one word illegible] has a stability coefficient equal to unity), the depth of freezing, from the condition of stability of the frozen layer, for the case when hydrostatic pressure is transmitted to its base, should satisfy the condition

$$b \geq \frac{0,5h^2}{\gamma_m h \cos\alpha + R^H_{dis} \sin\alpha}, \tag{3}$$

where γ_m is the density of the frozen soil of the slope, kg/m³; R^H_{dis} is the resistance of the frozen soil to the displacement, kg/m².

The [possibly weight] of [one word illegible] of the slope and [one word illegible] of the seasonal layer to depth [illegible], are not considered in the calculation.

If the depth of freezing of the upper slope, established by the [one word illegible] of the temperature mode of the dam, is less than b, determined on the basis of the recommended approximation procedure, then, to ensure the stability of the slope under conditions of inevitable, but insignificant freezing in terms of thickness, it is necessary to [one word illegible] from coarse-grain soil or rock fill.

In the presence of unfrozen natural infrabed thaw under the lower wedge, or in the presence of water in the lower reach [one word illegible] base of the slope of a thawed dam, failure of internal drainage and antifiltration systems may lead to the development of [one word illegible] filtration flow and deep thawing of the base of the lower wedge (Figure 2a). In this case it is necessary, when analyzing the strength of a frozen layer, to emphasize its [one or two words illegible] with permafrost foundation soils, and the action of forces of [one word illegible] need be considered only in plane A-A.

The usual calculations of the filtration resistance of the soils in the base of a dam are carried out for the section [three letters illegible]. The [possibly dynamic] characteristics of the seepage zone of the pressure-exerting filtration flow should be determined by the [four letter abbreviation illegible] method. [One word illegible] possibility of [possibly correcting] the dynamic pressure distribution on the [possibly lower] [possibly contour] of the water-impermeable layer (section [two letters illegible] in Figure 2b).

The time required for natural freezing of the slope to depth b, sufficient for absorbing the hydrostatic pressure in accordance with the recommended calculation technique, is determined in consideration of the assumption that freezing of the "[possibly thawed]" mass of a dam during the initial period of operation is not attributed to filtration.